Real Time Monitoring of an Aquaponic System Based on Internet of Things

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***Abstract*—Aquaponics is a system of aquaculture in which the waste produced by aquatic creatures are supplied as nutrients to plants growth hydroponically, which in turn purifies the water. This system can be made use of to produce organic food to meet the ever-growing need for food in the world. It also reduces the amount of water usage for cultivation by 80% and also 75% of the area requirement when compared to traditional farming. Since, the system consists of continuous cycling of the water, the quality of water should be periodically monitored. Manual monitoring of the system can be very tiring. Hence Internet of Things can be used as an effective application for this purpose. The system proposed consists of the continuous monitoring of both the water quality and the plants environment by using different sensors. The information collected by the sensors are accessed remotely by using the Internet of things. This will considerably reduce the human intervention in the system and also improve the efficiency of the system.**

***Index Terms*—Aquaponics, Internet of Things, Wireless sensor network, Environmental parameters.**

I. INTRODUCTION

AQUAPONICS is a combination of aquaculture and hydroponics in which aquatic creatures and plants are grown in one integrated system. This system has been in existence since ancient times. **Aquaponics** is a term that was coined in the 1970s, but the practice has ancient roots – although there is some debate on its first occurrence. The Aztecs cultivated a system of agricultural islands known as chinampas in a system considered by some to be the first form of **aquaponics** for agricultural use.

This system can be a ground-breaking food production technique with the application of latest trends in technology and techniques. It can be one of the solutions to the growing need for food in world. Since, the system can be used to grow a wide variety of food crops and edible fishes, it can be enough to produce a complete stable meal based on the size of the system designed.

The aquaponic system is a low-risk, high-profit farming method that requires little maintenance and expenditure once it's set up .It is also a 100% organic, chemical free, sustainable, with no weeds, no pests, no tilling the soil, no compost, no manure spreading, no watering, no rusty old tools, no tractor and all its extra costs. It can be simply said that the aquaponics system for growing crops is very easy and simple when compared to traditional methods of farming which involves a lot of hard work.

The aquaponic system can be very helpful to the farmers residing in areas with shortage of water. Most of our food requires 100s of liters of water for production of per crop area for cultivation. The daily drinking water requirement per person is 2-4 liters, but it takes 2000 to 5000 liters of water to produce one person's daily food. In such a situation, a method like aquaponics which is the combination of hydroponics and aquaculture, can contribute effectively to the problem by lowering the amount of water usage for cultivation by 80% and also 75% of the area requirement [1].

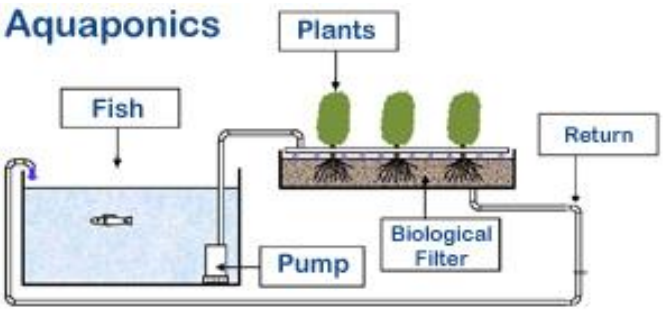

Figure 1.A simple basic model to help understand what a aquaponic system. Is.

II. TRADITIONAL AQUAPONICS

Aquaponics is one method of sustainable food production system in which aquaculture and hydroponics complement each other to make growing of different crops viable. With the two-

in-one process, the effluents that fish leaves in the water filter make the latter grow. Aquatic effluents refer to the remains or natural waste matters of the fish raise in a fish tank. These effluents make the tank water develop toxicity which could be harmful to the fish therein, but these are nutrients vital to the growth of the plants in the aquaponic system. Hence, the system calls for a component that would remove the effluents and pump out the water into the grow bed for plants. Thus, one of the major advantage of aquaponics is use of less water and spaces; producing less water waste and pollutants when compared to conventional method and using semi-skilled and local labor (if necessary) thus contributing to a sustainable livelihood.

Aquaponics is essentially a closed loop system except for the fish food which is to be provided separately for the fish. Other than that, the system is completely independent unlike the traditional farming. Since, it is a closed loop system it can be installed in any part of the world as it is not affected by a lot of external parameters provided that it is a properly designed system.

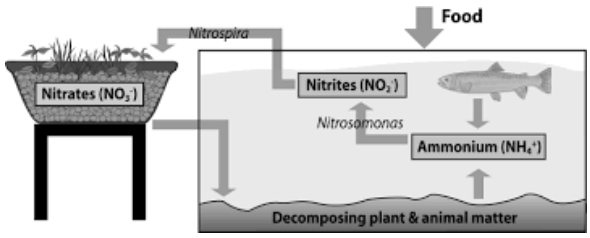

Figure 2. This depicts the nitrogen cycle and the traditional setup of a aquaponic system.

The figure above shows the process of how the nitrogen is cycled in the aquaponic system. The waste produced by the fish consists of the solid parts and the ammonia. This waste produced by the fish cannot be directly consumed by the plants. Hence, it needs to be converted into the form of nutrients that can be consumed by the plants. This process is done by the microorganisms. The detritivores convert the solid form of waste produced into nutrients that can be utilized by the plants. The ammonia or ammonium present in the waste is dangerous for the fish if left untreated. This is converted into plant absorbable nitrate(NO_3^-) by the nitrification process.

Nitrification is the process that drives most aquaponic systems. Nitrogen is one of the most important plant elements, but making it available depends very closely on the ability of system bacteria to add oxygen to ammonia and nitrite, which are both toxic, to produce nitrate which is a relatively benign form of nitrogen that is plant available. This process of oxidation is known as nitrification, and it serves a number of secondary functions in the system as well, including acidification of the system water.

Nitrification in nature is a two-step oxidation process of ammonium (NH_4^+) or ammonia (NH_3) to nitrate (NO_3^-) catalyzed by two ubiquitous bacterial groups. The first reaction is oxidation of ammonium to nitrite by ammonia oxidizing bacteria (AOB) represented by the "Nitrosomonas" genus. The second reaction is oxidation of nitrite (NO_2^-) to nitrate by nitrite-oxidizing bacteria (NOB), represented by the "Nitrobacter" genus.

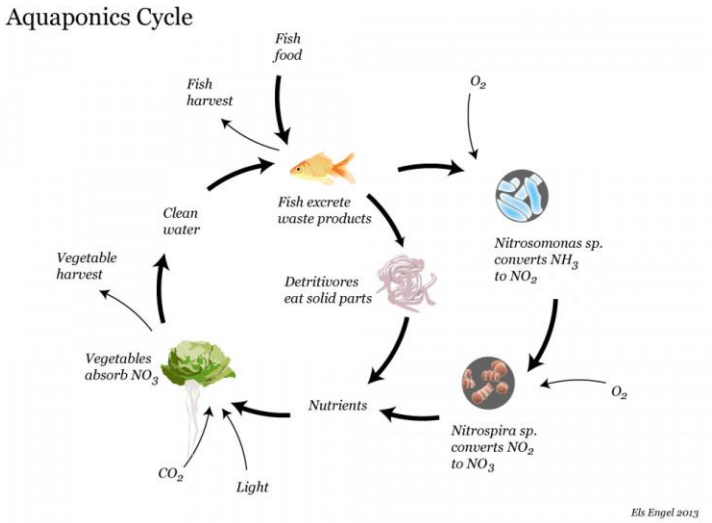

Figure 3.It Depicts the complete process of how the waste produced by the fish is converted into plant absorbable nutrients. It also shows the aquaponic cycle which occurs in the aquaponic system.

III. AQUAPONICS VS TRADITIONAL FARMING

The aquaponic system has a lot of advantages over the traditional farming techniques.

Table 1. Comparison between Traditional farming and Aquaponics

S.no	Traditional Farming	Aquaponics
1.	It requires a lot of water for growing crops.	It's usage of water is up to 90% less when compared to traditional farming.
2.	Harmful pesticides and other fertilizers may be used in the farming fields.	It is entirely organic and no harmful pesticides can be used as they are harmful for fish.
3.	The removal of weeds can be tiring and water used by weeds is wasted.	There is no chance for the growth of weed in the closed aquaponic system.
4.	The area required to grow the crops is very large.	An aquaponic system is four to six times as productive on a square foot basis as soil-based farming.
5.	We only get food crops from traditional farming.	We can get both the food crops and protein-rich fish out of an aquaponic system.

Thus, it can be inferred from the table that the aquaponic system has a wide range of advantages over the traditional farming. But still, Aquaponics has its own set of challenges that are to be overcome in order make the maximum use of this revolutionary concept of aquaponics.

IV. Environmental Parameters of an Aquaponic System

The aquaponic system must have a suitable environment for the well-being of both the fish and the plants. Hence, it is necessary to ensure that the environment is at suitable conditions required for the plant and fish to stay alive and thrive. The bacteria too have a threshold range within which they can develop. Hence, it is necessary to make sure that the environmental parameters are within the threshold of the tolerance range of the important three living groups in the system - the plants, fish and the bacteria.

Water is the medium through which plants receive their nutrients and the fish receive their oxygen. It is very significant to understand basic water chemistry and water quality in order to properly manage aquaponics. The plants, fish, and bacteria in Aquaponics systems entail adequate levels of water temperature, pH, and dissolved oxygen for maximum growth and health [3]

Some of the most common problems with aquaponics include increase in the temperature of the tank water, maintaining optimum PH for the plants to grow, frequent test of ammonia content in the tank, identifying and removing the diseased fishes. Certain tropical fishes would require ideal temperatures for their growth, thus requiring a method to regulate the temperature. The PH level in the fish tank drop to a PH level of 7.2 due to the characteristics of the fish wastes and plants grow in more acidic environment with PH levels 5.8 – 6.0. Build-up of ammonia in the system could prove fatal to the fishes and hence needs to be balanced. Profitably is highly unlikely in case of outbreak of any diseases to the fish and hence needs a continuous monitoring.

The ideal parameters for Aquaponics as a negotiation between all three organisms are specified in Table below.

Table 2. Ideal parameters for Aquaponic System

Parameter	Temperature(C)	pH	Ammonia(mg/L)	Nitirte(mg/L)	DO(mg/L)
Aquaponics	18-30	6-7	<1	<1	>5

These environmental parameters must be carefully se in the aquaponic system to make sure that they are suiting the conditions needed for the survival of the fish, bacteria and the plants.

V. Species that can be grown in a Aquaponic System

There are very little restrictions to decide what species of plants and fish can be grown in the aquaponic system. A wide range of species can be selected in both the fishes and the plants. But, it is necessary to make sure that the environmental parameters of the setup are suitable the particular species that are to be introduced into the system.

The fish and plants you select for your aquaponic system should have similar needs as far as temperature and pH [3]. There will always be some compromise to the needs of the fish and plants but, the closer they match, the more success that can be achieved.

As a general rule, warm, fresh water, fish and leafy crops such as lettuce and herbs will do the best. In a system heavily stocked with fish, you may have luck with fruiting plants such as tomatoes and peppers.

Some of the most commonly used species of fishes used in an aquaponic system are White bass, Barramundi, Crappies, Catfish, Trout, Jade Perch, Silver Perch, Goldfish.

The species of plants that can be grown in a aquaponic system can be decided only based on the size of the aquaponic system. Some of them can be grown in any system, some will be successful only in large scale aquaponic systems, whereas certain plants need a specially designed system to meet their requirements.

The table below classifies the different plants that can be grown in a aquaponic system. It must be noted that only certain plants are mentioned in the table below, and there is a wide range of other plants that can be used too.

Table 3. Plants that can be grown in this system

Plants that grow in any system	Plants with high nutritional needs that grow only in heavily stocked system	Other crops that can be grown under special conditions
✓ any leafy lettuce ✓ pakchoi ✓ kale ✓ swiss chard ✓ arugula ✓ basil ✓ mint ✓ watercress ✓ chives	✓ tomatoes ✓ peppers ✓ cucumbers ✓ beans ✓ peas ✓ squash ✓ broccoli ✓ cauliflower ✓ cabbage	✓ bananas ✓ dwarf pomegranate tree ✓ sweet corn ✓ micro greens ✓ beets, radishes ✓ carrots, onions ✓ nasturtium, violas, orchids

VI. Proposed Aquaponics Framework

The system proposed by us continuously records the various environmental parameters of the aquaponic system and makes it available to be accessed remotely by making use of the

Internet of Things. The Lumisense IoT Board is made use of for providing the IoT application for the aquaponic system

The proposed aquaponics system would require only very minimal manual intervention and yield great results with the help of technology. Here we will be making use of wireless sensor devices to identify and monitor the parts of the system that would require manual intervention and help further in automating the process thereby resulting in a self -sustainable, self-monitoring, self-maintaining aquaponics system.

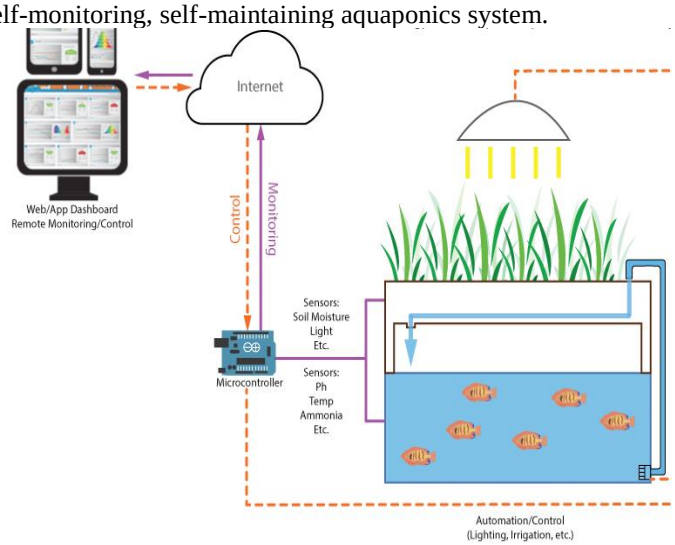

Figure 4.A model of the proposed aquaponic system making use of IOT.

The temperature, ammonia and pH sensors are placed in the fish tank which monitors the temperature, ammonia levels and pH levels while the ammonia sensor in the plant bed monitors the nitrate level. These sensors are necessary to monitor the system at all times. In case of any variations in the data, an alarm is given to the farmer to check the aquaponics setup. Variations mostly occur due to abnormality in the original setup.

The different parameters that are sensed are temperature, pH, ammonia levels, water level, soil moisture. The different sensors that are used to monitor the system are discussed below:

A. Temperature Sensor:

National semiconductor's LM35 IC has been used for sensing the temperature. It is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature. The temperature can be measured more accurately with it than using thermistor.

B. PH Sensor:

pH is a measure of how acidic or basic (alkaline) a solution is. In any given solution, some atoms of water dissociate to form hydrogen ions (H+) and hydroxyl ions (OH-). The Ph scale is a means of showing which ion has greater concentration. At a pH of 7.0, the concentrations of hydrogen ions and hydroxyl ions are equal, and the water is said to be neutral. Pure water has a pH of 7.0. When the pH is less than 7.0, there are more hydrogen ions than hydroxyl ions, and the water is said to be acidic. The lower and upper threshold value of pH are set is 7 and 8 respectively.

The Model PHE-45P pH Sensor used here measures the pH of aqueous solutions in industrial and municipal process applications. It is designed to perform in the harshest of environments, including applications that poison conventional pH sensors. All seals are dual o-ring using multiple sealing materials.

Figure 5.pH sensor

C. Ammonia Sensor(MQ137):

An ammonia sensor is placed in the tank to check for any variations. The fish waste is rich in ammonia which convert to become nitrates, the source of nutrients for the plants grown in water. The high levels of ammonia indicate that there is some abnormality in the fish tank. Major deviations in the ammonia values indicate that the fish waste from the fish tank are not optimal. Therefore, when there is any deviation in the nitrate value, the system is at risk and attention must be passed onto the fish tank.

Figure 6.ammonia sensor

D. Water level Sensor:

The water level sensor is used to monitor the water level in the tank in which the fishes are grown. This is necessary to make sure that the tank is always maintained at optimal water levels.

E. Moisture Sensor:

This sensor is used to measure the moisture in the plant grow bed. It helps to monitor the moisture levels in the growing medium of the plants. The Soil Moisture Sensor is used to measure the volumetric water content of soil. This makes it ideal for performing experiments in courses such as soil science, agricultural science, environmental

science, horticulture, botany, and biology. Use the Soil Moisture Sensor to: • Measure the loss of moisture over time due to evaporation and plant uptake. • Evaluate optimum soil moisture contents for various species of plants. • Monitor soil moisture content to control irrigation in greenhouses.

Figure 7.Soil moisture sensor.

The system proposed makes use of the above-mentioned sensors to continuously monitor the system. The information sensed by these sensors are fed into the Internet by the application of the Internet of things.

VII. Internet of Things

The Internet of Things (IoT) is an environment in which objects, animals or people are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. IoT has evolved from the convergence of wireless technologies, micro-electromechanical systems (MEMS) and the Internet. The concept may also be referred to as the Internet of Everything. A thing, in the Internet of Things, can be a person with a heart monitor implant, a farm animal with a biochip transponder, an automobile that has built-in sensors to alert the driver when tire pressure is low -- or any other natural or man-made object that can be assigned an IP address and provided with the ability to transfer data over a network.

The term "Internet of Things" (IoT) denotes a trend where a large number of embedded devices employ communication services offered by the Internet protocols. Many of these devices, often called "smart objects,'' are not directly operated by humans, but exist as components in buildings or vehicles, or are spread out in the environment.

Lumisense IoT board designed to meet a variety of online application needs with distinct advantages that enable the embedded system designer to easily, quickly and seamlessly add internet connectivity to their applications. The module's UART update feature and webpage control make them perfect for online wireless applications such as biomedical monitoring, environmental sensors, and datas from portable battery operated wireless sensor network devices. Lumisense IoT board featured with SIM900 GPRS modem to activate internet connection also equipped with a controller to process all input UART data to GPRS based online data.

VIII. Conclusion

While the concept of combining computers, sensors, and networks to monitor and control devices has been around for decades, the recent confluence of key technologies and market trends is ushering in a new reality for the "Internet of Things''. This technology when is used alongside innovative agricultural techniques such as Aquaponics can lead to new dimensions of food production. This will bring a solution to the ever-growing global food crisis.

Thus, it can be clearly seen that the frequent monitoring of an aquaponic system can be done tirelessly using the application of the Internet of Things technology.

References

[1] Design and deployment of wireless sensor networks for aquaculture monitoring and control based on virtual instruments, D.S. Simbeye et al./Computers and Electronics in Agriculture 102 (2014) 31–42.

[2] European Journal of Advances in Engineering and Technology, 2016, 3(2): 52-55, Shafeena T ,Department of Computer Science and Engineering, Govt. College of Engineering, Mananthavady, Wayanad, Kerala, India shafeenamea@gmail.com.

[3] An Autonomous aquaponic system using 6loWPAN,Sandhya Bhaskaran, et al/16 $31.00 © 2016 IEEE DOI 10.1109/W-FiCloud.2016.37

[4] *International Journal of Agriculture and Food Science Technology. ISSN 2249-3050, Volume 4, Number 10 (2013), pp. 975-980 978-1-5090-3946-3/16 $31.00 © 2016 IEEE DOI 10.1109/W-FiCloud.2016.37Transmission Systems for Communications*, 3rd ed., Western Electric Co., Winston-Salem, NC, 1985, pp. 44–60.

[5] The Internet of Things: An Overview Understanding the Issues and Challenges of a More Connected World © 2015 The Internet Society (ISOC). *Example:*

[6] The Way of the Future: Aquaponics vs.Traditional Agriculture Written by Sylvia Bernstein, http://innerself.com/content/living/home-and-garden/gardening/8654-aquaponics-vs-traditional-agriculture.html.

[7] BENEFITS OF AQUAPONICS, http://www.volcanoveggies.com/benefits-of-aquaponics/

[8] https://aquaponics.com/recommended-plants-and-fish-in-aquaponics/

[9] Aquaponics Growing Fish and Plants Together Presented by: JD Sawyer